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(54) IMPROVEMENTS IN AND RELATING TO METHODS OF PRESSURE  
 BONDING A CERAMIC MEMBER TO ANOTHER MEMBER

- (71) We, MULLARD LIMITED, of Abacus House, 33 Gutter Lane, London, E.C.2., a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- This invention relates to a method of securing a ceramic member to another member which is of metal or ceramic material by pressure bonding.
- It is known to join a ceramic member to another member of ceramic material or metal by the methods of sintering, brazing, and reflow soft soldering. The use of sintering involves the disadvantage of the members being subjected to very high temperatures which approach the melting point of at least one of the materials of the members. The use of brazing techniques often has the disadvantage that the ceramic facing surface or surfaces require a metallisation which is expensive and the temperatures required in brazing may give rise to cracking of the ceramic material due to stresses caused by the brazing process. Some soft soldering methods are unsuitable in certain applications because the soldering temperatures required may be higher than is desirable having regard to other components present in the system of which the two members to be secured form part.
- According to the invention there is provided a method of securing a ceramic member to another member which is of metal or ceramic material by pressure bonding, wherein between substantially flat facing surfaces of the two members there is applied a malleable metal body and a mechanical bond between the members via the intermediate malleable body is obtained by pressing the members together in a press at a steady pressure normal to said flat surfaces of between 1 and 5 tons per square inch at a temperature above ambient but below the melting point of the malleable metal body at said pressure and below the lowest temperature at which a liquid phase would form at said pressure by interaction of the elemental components of the malleable metal body and members at the facing surfaces, said pressure and temperature being together applied to achieve within a period not exceeding 30 seconds a bond between the members having a bond tensile strength minimally of 20% of the Ultimate Tensile Strength of the malleable metal body.
- In this method a strong bond is achieved in a relatively simple manner. Examples of ceramic materials which may be used in the method are refractory oxide materials such as alumina, beryllia and zirconia.
- The said pressure range is chosen with the upper limit of 5 tons per square inch in order to avoid fracture of the ceramic member or members. The lower limit of 1 ton per square inch is chosen because it is found that pressures below this value do not yield a suitable bond or the bond obtained is of insufficient strength. The temperature at which bonding is effected may be relatively low in comparison to the temperatures employed in the prior art reflow soldering methods utilising similar materials. The period during which the said pressure and temperature are applied may be relatively short and in many applications not more than 5 seconds. This short bonding time coupled with the relatively simple means required to make the bond yields a relatively cheap production process. For any particular bonding operation the period during which the said pressure and temperature are applied is such that the bond achieves a desired tensile strength which is at least 20% and in general approximately 50% of the Ultimate Tensile Strength (UTS) of the malleable metal body used. Sometimes, however, measurement of this is limited by the tensile strength of the ceramic body which if low will cause the ceramic body to fracture before the bond is broken when under test. In some forms of the method where a high tensile strength bond is not required, the period during which the said temperature and pressure are applied may be such that the resultant bond has a tensile strength

which is only 20% to 25% of the Ultimate Tensile Strength (UTS) of the malleable metal body. When a bond strength of 50% of the Ultimate Tensile Strength (UTS) of the malleable metal body is obtained, maintaining the assembly under the said pressure and temperature for a longer period will not appreciably increase the bond strength, that is it will not increase the bond strength by more than 20%.

The exact physical mechanism by which the bond is obtained is not fully understood. However the temperature conditions are such that no melting occurs of the malleable metal body at the facing surfaces and no liquid phase is formed by interaction of the elemental components of the malleable metal body and members at the facing surfaces. Furthermore with such a short period for the bonding time no long range diffusion of the elements takes place, although some short range diffusion, that is having a depth of a few atoms, may take place.

A further advantage of the method in accordance with the invention is that compared with the prior art methods of sintering, brazing or soldering any strain produced in the ceramic body or bodies is relatively small, mainly due to the lower temperatures that can be used in this method of pressure bonding thus reducing the effect of any difference in coefficients of expansion of the components and due to the fact that when using a flat malleable metal body, for example in the form of a metal foil, there is a small creepage of the malleable material in the lateral direction between the facing surfaces. Furthermore in some cases, for example when using a malleable metal body of soft solder, the bonding occurs without the formation of intermetallics that would occur with conventional soldering and this is a contributory factor in the strain being low.

In one form of the method in accordance with the invention the malleable metal body is in the form of a metal foil and the conditions of pressure and temperature are such that the deformation of the malleable foil is less than 5%, for example less than 2%, the deformation being the difference in the thickness divided by the original thickness expressed as a percentage.

The facing surface of at least one of the two members may be provided with a metal coating which may or may not differ from the material of the malleable metal body, the requirement for such a coating depending upon the material of the members and the material of the malleable metal body. Generally when a metal member is to be secured to a ceramic member a metal coating, for example of gold, is required on the facing surface of the metal member for those metals whose surfaces readily oxidise. The requirement for a ceramic facing surface or

surfaces to be metallised depends upon the material of the malleable metal body used, for example when using a malleable metal body of gold or soft solder it is generally required to metallise the ceramic facing surface or surfaces with a material commonly used for ceramic metallisation such as gold, gold/palladium or silver/palladium. However when using an aluminium foil it may not be necessary to metallise the ceramic facing surface or surfaces, for example bonding a metal or ceramic member to an alumina member with an aluminium body may not necessitate the metallisation of the facing surface of the alumina member.

Various metals may be used for the malleable metal body and the particular choice of metal is dependent upon the materials of the two members to be secured and the admissible temperatures which can be applied in securing the members. One such metal is gold and when using a gold foil a thickness of at least 10 microns is preferred. A gold metallising layer may be applied to the ceramic facing surface or surfaces when using a malleable metal body in the form of a gold foil. Preferred bonding conditions using a gold body are under pressures of between 2.5 and 3.5 tons per square inch and at temperatures in the range of 300°C to 350°C.

Another metal suitable for the malleable metal body is aluminium and when in the form of a foil a thickness of at least 10 microns is preferable. Preferred conditions of bonding when using aluminium bodies are under pressures of between 2.5 and 3.5 tons per square inch and at temperatures in the range of 350°C to 450°C.

The malleable metal body may be of soft solder material having a melting point in the range of 125°C to 330°C and bonding may be effected at a temperature in the range of 75°C to 300°C, subject to the chosen temperature being lower than the melting point of the solder material and below the temperature at which any liquid phase could form by interaction of the elemental components of the solder material and members present at the facing surfaces.

The soft solder foil may be one of a range of soft solder materials having lead as the primary constituent and melting points in the range of 285°C to 327°C, for example in the range of 300°C to 327°C. One such material is of lead, silver and tin in which the percentages by weight respectively are 95, 3.5 and 1.5 and the melting point is 317°C. Another such material has the same constituents with the respective percentages by weight being 95.5, 3.0 and 1.5, the melting point is 306°C. When using such soft solder materials having lead as the primary constituent, pressures in the range of 2.5 to 3.5 tons per square inch and bonding temperatures in the range of 190°C to 290°C

are preferred, for example in the range of 240°C to 290°C.

5 The malleable metal body may be one of a range of soft solder materials having lead and tin, cadmium and tin, lead and indium, lead and cadmium and tin, or lead and silver and tin as constituents and having melting points in the range of 150°C to 300°C. Using such materials preferred bonding conditions are under pressures of between 2.5 and 3.5 tons per square inch and at temperatures of between 100°C and 280°C subject to the temperature chosen being lower than the melting point of the solder foil and lower than the temperature of any liquid phase that may form by interaction of the elemental components of the solder materials and members present at the facing surfaces. In this group of materials one preferred range of compositions is of solder materials of lead and indium having melting points in the range of 235°C to 260°C, bonding being carried out advantageously at a temperature in the range of 180°C to 200°C.

25 The malleable metal body may be one of a range of soft solder materials having indium as the primary constituent and having melting points in the range of 125°C to 160°C. Using such materials preferred bonding conditions are under pressures of between 2.0 and 3.0 tons per square inch and at temperatures of between 75°C and 150°C subject to the temperature chosen being lower than the melting point of the solder material and lower than the temperature of any liquid phase that may form.

In one form of the method one member is of copper and the other member is of ceramic material, for example of beryllia, these members being secured via an intermediate soft solder body of lead and indium. At the facing surfaces the ceramic member may comprise an applied gold coating and the copper member has a plating comprising gold. The temperature of bonding may be between 190°C and 200°C and the pressure approximately 3 tons per square inch.

In another form of the method one member is of nickel and the other member is of ceramic material, for example of beryllia, these members also being secured via an intermediate soft solder body of lead and indium under the same conditions as referred to in the previously described preferred form.

In another form of the method the two members are of alumina and are secured together by pressure bonding via an intermediate soft solder body of cadmium and tin, the facing surfaces of the alumina members being provided with coatings of silk screen printed alloy of palladium and silver. The temperature of bonding may be between 150°C and 175°C.

65 Embodiments of the method in accord-

ance with the invention will now be described, by way of example, with reference to the diagrammatic drawings accompanying the Provisional Specification, in which:—

Figure 1 is a vertical section of part of a press apparatus which may be employed in a method in accordance with the invention;

Figure 2 shows a cross-sectional view of a supporting assembly for a transistor module comprising a beryllia member which at its lower side is pressure bonded to a copper plinth and at its upper side has pressure bonded nickel lead-in members, this Figure serving to illustrate two specific applications of the method in accordance with the invention;

Figure 3 shows in cross-sectional view and in exploded form the various components present in the assembly shown in Figure 2 prior to their attachment by application of a method in accordance with the invention; and

Figure 4 shows in cross-sectional view and in exploded form parts of an envelope for an electronic device, said parts comprising two alumina members which in the sealing of the envelope are joined by a pressure bonding method in accordance with the invention.

Referring first to Figure 1, the press comprises a fixed steel supporting base 1 and a movable press head 2. A steel pedestal 3 of circular section is secured to the supporting base which also carries an asbestos support 4. On the asbestos support 4 there is a silica tube 5 which is coaxial with and surrounds the upper portion of the steel pedestal 3. A wire heater element 6 is wound around the silica tube 5. The heater element 6 and silica tube 5 are surrounded by an outer brass cover 7 which at its lower end is supported on the asbestos support 4 and at its upper end supports an asbestos cover 8. On the upper surface of the steel pedestal there is secured a steel support base 9 which is machined from material available from Kayser-Ellison as K.E. 970 tool steel which is a high duty tool steel which has been hardened and tempered. In the side of the support base 9 there is an aperture 10 for the insertion of a thermocouple (not shown). In the side wall of the outer brass cover 7 there is an opening 11 for inlet of mixed gas (10% hydrogen in nitrogen) to provide a controlled atmosphere around the components when being pressure bonded and to prevent oxidation of the opposing tool faces. In the asbestos cover 8 there is a plurality of apertures 12 for outlet of the gas.

The movable steel press head 2 has a steel insert 15 secured in its lower surface. Two steel plates 16 and 17 are secured to the insert 15 together with a rubber shock absorber pad 18 which is sandwiched between the plates 16 and 17. A bolt 19 secures the

assembly of the plates 16 and 17 and the pad 18 to the insert 15, the head of the bolt 19 extending inside a steel cup member 20 which is attached to the insert 15. The cup member 20 is internally threaded and locates an externally threaded end pressure plate 21 also of K.E. 970 tool steel. On the lower peripheral surface of the steel cup member 20 there is an asbestos insulator 22. The end pressure plate 21 has a peripheral rim 23 and between the rim 23 and the asbestos insulator 22 there is a flat NICHROME (Registered Trade Mark) heater member 24 between two mica plates 25. The end pressure plate has an aperture 26 for insertion of a thermocouple element. The outer surface of the plate 17 has a water cooling tube 27 attached thereto.

The operation of the press apparatus in a method in accordance with the invention will now be described. With the movable press head 2 in the position shown in Figure 1, the gas supply and heater elements 6 and 24 are switched on and the temperatures adjusted until the steel support base 9 and the end pressure plate 21 are at the desired bonding temperature. The assembly of the two members to be secured and the intermediate malleable metal body is placed on the surface of the steel support base 9 and the movable press head 2 is lowered so that the end pressure plate 21 bears on the upper surface of the upper member. The pressure of the end pressure plate 21 is then increased gradually over a period of 5 to 10 seconds until the desired bonding pressure is obtained, for example 2.5 tons per square inch. This pressure is then maintained for the desired time in a duration substantially normal to the flat surfaces of the two members to be secured, for example approximately 10 seconds, and thereafter the pressure is released by upward movement of the press head 2 and finally the assembly of the members which are bonded via the intermediate malleable metal body is removed. Generally the heater elements 6 and 24 will be controlled to maintain the support base 9 and end pressure plate at the same temperature but these temperatures may if desired be varied independently. The control obtainable is  $\pm 2^\circ\text{C}$  and is achieved via thermocouples in the apertures 10 and 26 and a temperature controller. The pressure and pressure build-up is controlled via a standard needle valve control and hydraulic clutch.

Referring now to Figure 2 there is shown in section a supporting assembly for a transmitting transistor module. The assembly comprises a rectangular copper base member 31 of 16 mm.  $\times$  32 mm.  $\times$  1.6 mm. thickness plated with nickel and gold. A copper plinth 32 of 11 mm.  $\times$  8 mm.  $\times$  1.6 mm. thickness also plated with nickel

and gold is pressure bonded to the base 31 via an intermediate soft solder foil 33. A beryllia member 34 of 11 mm.  $\times$  8 mm.  $\times$  1.0 mm. thickness is pressure bonded to the copper plinth via an intermediate soft solder foil 35. On the upper surface of the beryllia member 34 there is a screen printed conductive pattern of gold of approximately 15 microns thickness. On the lower surface of the beryllia member 34 there is a gold metallisation layer 36 of 15 microns thickness. Three lead-out conductor terminal strips of which two strips 37 and 38 are shown in the section of Figure 2 are pressure bonded to connection pad portions 39 of the gold pattern at the upper surface of the beryllia member 34 via intermediate soft solder foil bodies 40. The terminal strips are of nickel of approximately 13 mm.  $\times$  2 mm.  $\times$  100 microns thickness plated with gold and extend laterally beyond the copper base 31. On each of three further pad portions of the gold pattern, of which only one such portion 41 is shown in the section of Figure 2 silicon transistor elements can be bonded.

The manufacture of the assembly shown in Figure 2 will now be described with reference to Figure 3. The copper base member 31 and the copper plinth 32 are plated with nickel (2 microns) and then gold (0.1 micron). The conductive pattern of gold of 15 microns thickness and comprising the portions 39 and 41 is provided on the beryllia member 34 by a conventional silk screen process and a gold layer 36 of the same thickness is provided over the whole area of the opposite surface of the beryllia member 34. The nickel terminal strips are provided with a thin gold plating on all surfaces. The three terminal strips, of which only the strips 37 and 38 are shown in Figures 2 and 3, are then bonded to the beryllia member 34 by a method in accordance with the invention and with an apparatus as shown in Figure 1. This involves the placing of the beryllia member 34 on the support base 9, placing soft solder foil bodies 40 on the pad portions 39 of the gold pattern, and placing the strips on the solder bodies. The solder bodies 40 are of lead and indium in which the respective percentages by weight are 72% and 28%, this material having a melting point of  $260^\circ\text{C}$ . The bodies 40 are of 2 mm.  $\times$  2 mm.  $\times$  60 microns thickness. Bonding is effected at a temperature in the range of  $190^\circ\text{C}$  to  $200^\circ\text{C}$ , a pressure of 3 tons per square inch and for a period of 10 seconds.

Subsequently the beryllia member 34 having the terminal strips secured thereto is pressure bonded by a method in accordance with the invention to the copper plinth 32 and simultaneously therewith the copper plinth 32 is pressure bonded to the base 31. This is carried out with an apparatus as

shown in Figure 1 and the components are assembled on the support base 9. Between the copper base 31 and the copper plinth 32 there is placed a soft solder foil body 33 having a thickness lying in the range of 250 to 500 microns, in this case of 400 microns thickness. The surface dimensions of the foil body are 11 mm.  $\times$  8 mm. The foil is of lead and indium in which the respective percentages by weight are 72% and 28%. A foil body 35 of the same composition and dimensions is placed between the upper surface of the copper plinth 32 and the lower surface of the beryllia member 34. Bonding is effected at a temperature in the range of 190°C to 200°C, a pressure of 3 tons per square inch and for a period of 10 seconds.

Subsequent to obtaining the assembly shown in Figure 2, silicon transistor elements may be secured on the pad portions 41 of the gold pattern by a pressure bonding method as described and claimed in our United Kingdom Patent Specification No. 1,389,542. Thereafter a plurality of passive circuit elements are secured on the surface of the beryllia member 34 with the aid of an adhesive, interconnections are established between the circuit elements and the conductive gold pattern and finally the device is encapsulated in silicone plastic leaving the three flat lead-in terminals projecting beyond the encapsulation.

Other soft solder materials as described herein may be used for the pressure bonding of the terminal strips to the beryllia member 34 and for the pressure bonding of the beryllia member 34 to the copper plinth 32. The material of conductive pattern on the surface of the beryllia member 34 and also the coating 36 may be other than of gold, for example of an alloy of silver and palladium ink which has been fired after application to the beryllia surface.

Referring now to Figure 4 a further embodiment of the pressure bonding method in accordance with the invention will be described, the members being secured in this embodiment both being of ceramic material. The Figure shows the component parts of an electronic device envelope. The parts comprise an alumina base plate 51 of 3.0 cm.  $\times$  3.0 cm.  $\times$  2 mm. thickness having a silk screen printed conductive pattern of an alloy of palladium and silver thereon of 8 microns thickness, strip parts 52 and 53 of said pattern being shown in the section of the Figure and forming lead-in conductor parts. A wall member 54 of rectangular outline consists of alumina and is sealed onto the base plate 51 with a glass sealing 55, this glass sealing also extending between the strip parts 52 and 53 of the conductive pattern and the alumina wall member. The wall member 54 of alumina has a width of 4.0 mm. and a thickness of 3.0 mm. On the upper surface of

the wall member 54 there is a metallisation 56 consisting of an alloy of palladium and silver of 8 microns thickness. An alumina lid member 57 of 2.5 cm.  $\times$  2.5 cm.  $\times$  2.0 mm. thickness serves as a closure for the envelope and this is pressure bonded to the alumina wall member 54 by a method in accordance with the invention using an intermediate foil body 58 of a solder material consisting of an alloy of cadmium and tin in which the respective percentages by weight are 34% and 66% and having a melting point of 117°C. The foil is of rectangular outline having a width of 3.5 mm. and a thickness of 50 microns. The lower surface of the alumina lid 57 is provided with a metallisation layer 59 of a silk screen printed alloy of palladium and silver. The layer is also of rectangular outline of 4.0 mm. width and 8.0 microns thickness. The pressure bonding is effected in an apparatus as shown in Figure 1 at a temperature of 165°C, a pressure of 2.5 tons per square inch and for a period of 5 seconds.

Many variations are possible within the scope of the invention. For example in Figure 4 the alumina lid member 57 may be secured to the alumina wall member 54 using a different material, for example a solder material of lead, silver and tin. The precise choice of the material of the malleable metal layer depends partly on the nature of the electronic component or components provided within the envelope and the ability of such components to withstand the bonding temperature that is required for each specific material. Thus in general the lead based solders will require higher bonding temperatures than the described example using a cadmium and tin solder. Instead of a body in the form of a foil having a rectangular cross-section it is possible in some applications to use a malleable metal body of circular cross-section such as a wire and this is particularly suitable where the bonding conditions may be such as to cause the facing surface of one of the members to become slightly curved.

In our United Kingdom Patent Specification No. 1,389,542 there is described and claimed a method of securing a semiconductor body, for example of silicon, germanium or gallium arsenide, to a support by a pressure bonding method. In the present specification the term "metal number" is not to be interrupted in such a wide sense as to include a semiconductor body.

#### WHAT WE CLAIM IS:—

1. A method of securing a ceramic member to another member which is of metal or ceramic material by pressure bonding, wherein between substantially flat facing surfaces of the two members there is applied a malleable metal body and a

- mechanical bond between the members via the intermediate malleable body is obtained by pressing the members together in a press at a steady pressure normal to said flat surfaces of between 1 and 5 tons per square inch at a temperature above ambient but below the melting point of the malleable metal body at said pressure and below the lowest temperature at which a liquid phase would form at said pressure by interaction of the elemental components of the malleable metal body and members at the facing surfaces, said pressure and temperature being together applied to achieve within a period not exceeding 30 seconds a bond between the members having a bond tensile strength minimally of 20% of the Ultimate Tensile Strength of the malleable metal body.
2. A method as claimed in Claim 1, wherein said pressure and temperature are together applied to achieve within a period not exceeding 30 seconds a bond having a bond tensile strength of approximately 50% of the Ultimate Tensile Strength of the malleable metal foil or wire.
3. A method as claimed in Claim 2, wherein said pressure and temperature are together applied for a period not exceeding 5 seconds.
4. A method as claimed in any of Claims 1 to 3, wherein the malleable metal body is in the form of a substantially flat foil and the conditions of pressure and temperature are such that the deformation of the malleable metal foil is less than 5%.
5. A method as claimed in any of Claims 1 to 4, wherein the malleable metal body is of a soft solder having a melting point in the range of 125°C to 330°C and bonding is effected at a temperature in the range of 75°C to 300°C.
6. A method as claimed in Claim 5, wherein the soft solder is one of a range of soft solder materials having lead as the primary constituent and melting points in the range of 285°C to 327°C.
7. A method as claimed in Claim 6, wherein bonding is effected at a pressure in the range of 2.5 to 3.5 tons per square inch at a temperature in the range of 190°C to 290°C.
8. A method as claimed in Claim 5, wherein the soft solder is one of a range of soft solder materials having lead and tin, cadmium and tin, lead and indium, lead and cadmium and tin, or lead and silver and tin as constituents and having melting points in the range of 150°C to 300°C.
9. A method as claimed in Claim 8, wherein bonding is effected at a pressure in the range of 2.5 tons and 3.5 tons per square inch and at a temperature in the range of 100°C to 280°C.
10. A method as claimed in Claim 8, wherein the soft solder is one of a range of soft solder materials having lead and indium as constituents and having melting points in the range of 235°C to 260°C, the bonding being effected at a temperature in the range of 180°C to 200°C.
11. A method as claimed in Claim 5, wherein the soft solder is one of a range of soft solder materials having indium as the primary constituent and having melting points in the range of 125°C to 160°C.
12. A method as claimed in Claim 11, wherein bonding is effected at a pressure in the range of 2.0 and 3.0 tons per square inch and at a temperature in the range of 75°C to 150°C.
13. A method as claimed in any of Claims 1 to 5, wherein one member is of ceramic material and the other member is of copper, said members being secured by pressure bonding via an intermediate soft solder body of lead and indium.
14. A method as claimed in Claim 13, wherein the ceramic member is of beryllia and at the facing surfaces the beryllia member has an applied coating of gold and the copper member has a plating comprising gold.
15. A method as claimed in any of Claims 1 to 5, wherein one member is of beryllia and the other member is of nickel, said members being secured by pressure bonding via an intermediate soft solder body of lead and indium.
16. A method as claimed in Claim 15, wherein at the facing surfaces the beryllia member has an applied coating of gold and the nickel member has a gold plating.
17. A method as claimed in any of Claims 1 to 5, wherein the two members are of alumina and are secured by pressure bonding via an intermediate soft solder body of cadmium and tin.
18. A method as claimed in Claim 17, wherein the facing surfaces of the alumina members are each provided with a coating of an alloy of palladium and silver.
19. A method as claimed in any of Claims 1 to 4, wherein the malleable metal body is of gold and bonding is effected at a pressure of between 2.5 and 3.5 tons per square inch and at a temperature in the range of 300°C to 350°C.
20. A method as claimed in any of Claims 1 to 4, wherein the malleable metal body is of aluminium and bonding is effected at a pressure of between 2.5 and 3.5 tons per square inch and at a temperature in the range of 350°C to 450°C.

21. A method of securing a ceramic  
member to another member substantially as  
herein described with reference to Figures 1  
to 3 or Figures 1 and 4 of the drawings  
5 accompanying the Provisional Specification.

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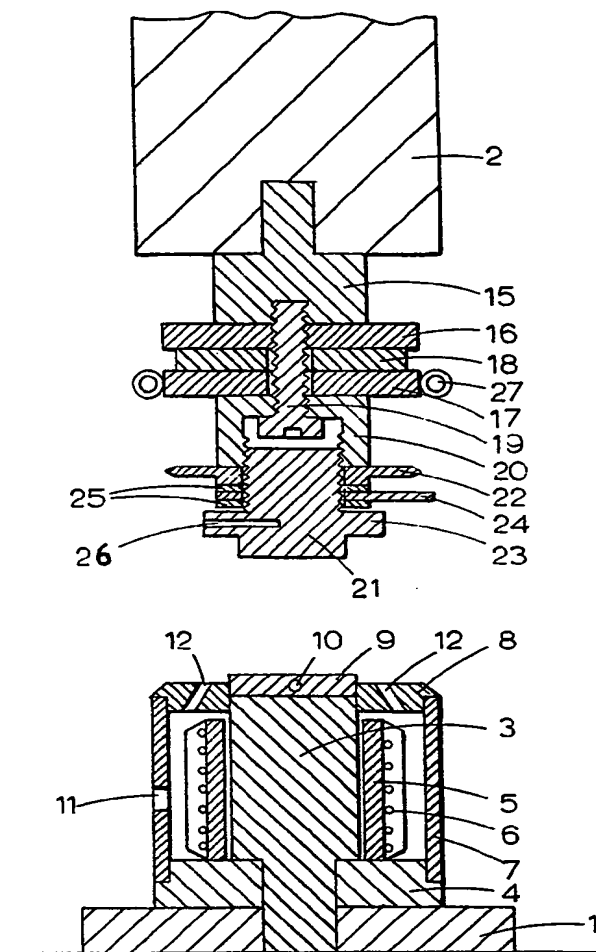


Fig.1.



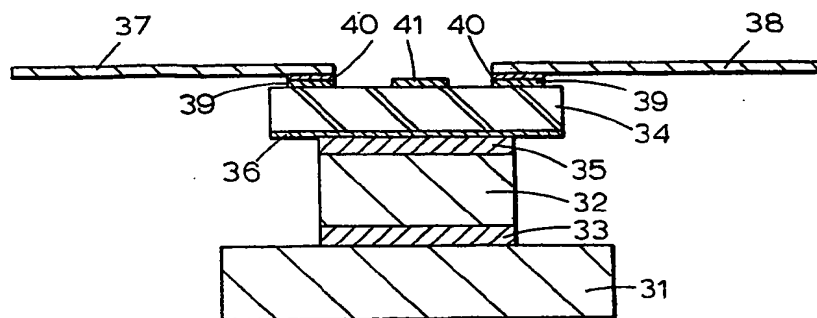


Fig. 2.

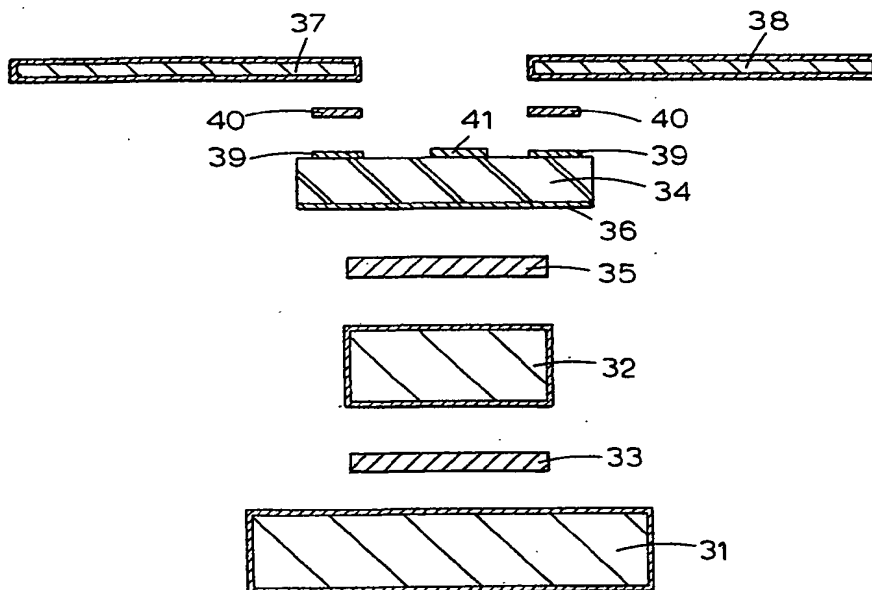


Fig. 3.

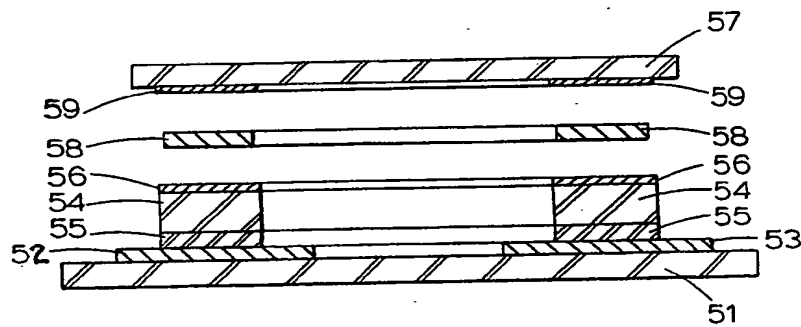


Fig. 4